ROOTING CHARACTERISTICS OF VEGETATION ESTABLISHED ON A REFUSE PILE

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ABSTRACT

Established vegetation growing on a reclaimed refuse pile at the Starpoint Mine was compared with vegetation growing on a subsoil stockpile. Both were seeded in 1983. Soil cover over refuse varied from two inches to eighteen inches. Five pits were excavated in the refuse pile and five pits in the subsoil pile adjacent to shrubs common in both locations. Root sizes and quantities were estimated based on the 1998 NRCS publication, Field Book for Describing and Sampling Soils.[1] Soil texture, coarse fragment content, and structure were noted. Representative samples of field measurements of soil pH and electrical conductivity were taken. Resistance to penetration was measured with a pocket penetrometer.

Taproots of all shrubs, except Eriogonum corymbosum, dramatically turned to grow along the soil/refuse interface before eventually descending gradually, but not vertically, into the refuse. A mat of fine roots formed at the soil/refuse interface. Medium and coarse roots were limited to the top two feet of the subsoil-covered refuse. At the subsoil pile, all shrub taproots were quite robust and grew straight downwards into the subsoil stockpile as did medium and coarse roots. The subsoil was impenetrable when dry, similar to the refuse. However, when it was moist, resistance to penetration was much lower than the refuse. Avoidance of the refuse by the taproots was likely due to compaction of the refuse and enhanced water availability of the subsoil stockpile.

Root growth into refuse would be enhanced by ripping of the surface prior to soil cover placement. The recommended depth of ripping is inversely related to the depth of cover, so that a less compacted root zone of four feet is achieved. If the refuse is combustible then the recommended soil cover depth should be four feet to allow for a rooting zone, while protecting against combustion. Working the soil cover into the refuse surface to avoid an abrupt boundary layer is also recommended.

[1] Schoeneberger, P.J. Wysocki, D.A., Benham, E.C., and Broderson, W.D. 1998 Field Book for describing and sampling soils. Natural Resources Conservation Service, USDA, National Soil Survey Center, Lincoln, NE.

INTRODUCTION

Refuse piles are a significant component of mined land reclamation in Utah. While the coal refuse in Utah is generally considered non-toxic, it is unknown whether it provides a suitable root growth medium. Evaluation of rooting depths on coal refuse piles was selected as an evaluation topic to investigate the suitability of coal refuse as a plant growth medium.

The evaluation was conducted at the Star Point Mine refuse pile on the ridge above the test plots. The test plots were established in 1983 to evaluate varying depths of topsoil, subsoil, and fertilizer on vegetative cover. The vegetation is now 17 years old and has established, well-developed root systems.

A backhoe was used to excavate five pits in the refuse pile and five pits in the subsoil pile. The pits were dug no deeper than five feet because of safety concerns. Pit locations were based on the presence of three shrubs common to each location and equipment accessibility. We anticipated that this would enable us to make paired comparisons, where the only variable was the presence of refuse or subsoil below the topsoil.

Root size and quantity was estimated based on the 1998 NRCS publication, Field Book for Describing and Sampling Soils (Schoeneberger et al, 1998). Soil and refuse conditions were assessed similar to a soil survey. Estimates of the soil texture, coarse fragment content, and structure at different depth intervals were taken. Representative samples of field measurements of soil pH and electrical conductivity were taken. Each pit was photographed.

Field reconnaissance work was completed in May and August of 2001. We compared the rooting depths and distributions found in the refuse and subsoil areas. We also compared these patterns and depths with rooting depths reported in the literature. Any differences in root growth patterns and physical differences between the refuse and subsoil were noted.

SITE DESCRIPTION AND LITERATURE REVIEW

Typical root growth characteristics are summarized in Table 1 below. Munshower (1995) states that root growth is strongly influenced by the soil in which the root is growing. For instance, *Artemisia tridentata* may be a deep taproot with a wide lateral spread or a short taproot with many branches.

Table 1. Typical root growth characteristics*

Species	Root type	Depth (ft)	Height (ft)
Artemesia tridentate	One or more tap roots. 1/3 of roots in top foot of soil	6	2-4
Atriplex canescens	Branching tap root	6.5 – 20	1-7
Chrysothamnus nauseosus	Branching tap root	deep	1-7

Ephedra	Several deep tap roots subdivide at intervals	deep	0.75 – 5.0

*Munshower, 1995; Brown and Wiesner, 1984; USDA Fire Sciences Laboratory, July 2001.

The Star Point Mine annual reports indicate that the mine weather station recorded an average of 13.78 inches precipitation for the years 1984 to 1991. The highest annual precipitation recorded was 21.07 inches in 1985; the lowest annual precipitation recorded was 8.97 inches in 1989. The weather station was located at an elevation of 8550 feet until July 1989 when it was moved to 7560 feet elevation. Information specific to Star Point Mine is not available after 1991, as the weather station was disabled by a lightening strike (Personal communication, 2001).

In a 1977 report, Dames and Moore described the Star Point refuse as waste from the wash plant and mine composed of mudstone, shale and coal. The refuse was classified as a well-graded, silty, fine-to-coarse sand with fine and coarse gravel and occasional cobbles (Dames & Moore, 1977). They recommended a compaction of 75 pounds per cubic foot for the refuse material when it was placed in the test plot area of the refuse pile sometime between 1976 and 1982. A 1982 photograph of the refuse prior to installation of the test plot shows a two-track road going up the ridge of the pile. Our rooting depth study pits were in the same approximate location as the road.

The Star Point Mine refuse pile test plots test plots were planned to evaluate topsoil and subsoil replacement depths necessary for successful plant growth. The test plots and surrounding area were seeded in 1983 and the following seed mixture was reportedly used.

Table 2. Seed mixture reported used on the refuse pile.

Species	Lbs. PLS/Acre
Slender wheatgrass	3
Western wheatgrass	3
Tall fescue	2
Great Basin wild rye	3
Bluebunch wheatgrass	3
Scarlet globemallow	.5
Penstemon	.5
Cicer milkvetch	1
Yellow sweet clover	1
Rubber rabbitbrush	.5
Big sagebrush	.1
Green ephedra	2
Fourwing saltbush	1
Total	20.6

Table 3 summarizes the characteristic of the refuse and subsoil as reported in the Star Point Mining and Reclamation Plan. As Table 2 illustrates, the average refuse pH was 7.1 with a high of 7.9 and a low of 6.6. The average electrical conductivity (EC) was 3.76 (high of 8.8 and low of 1.2). The average sodium adsorption ratio (SAR) was 1.61, with a high of 5 and a low of 0.3. On the average, particle fractionation was 59% percent sand, 23% silt, and 18% clay, placing the refuse texture in the sandy loam category. The average nitrogen level was 3.76. Overall, the refuse had a higher salt content than the subsoil, but not sufficient to affect plant growth. The refuse was also coarser textured than the spoil.

Table 3. Comparison of subsoil and refuse chemical and physical parameters as reported in the MRP.

Parameter	**Subsoil**	**Refuse**
PH (units)	7.9	7.1
EC (mmhos)	0.54	3.76
Ca (Meq/l)	399	38
Mg (Meq/l)	67	16
Na (Meq/l)	1	7
SAR (units)	0.22	1.16
Sand (%)	38	59
Silt (%)	31	23
Clay (%)	31	18
Texture (Average)	Clay loam	Sandy loam

In the year 2001, the refuse pile was well vegetated and was growing species which were not seeded, such as the Sego Lily. The Utah Regulatory Program Evaluation Year 2000, Evaluation Topic: Reclamation Success on Refuse Piles, dated 10/18/2000, reported that the average vegetative cover on the reclaimed refuse test plots was 32.3% and met the 90% standard of the designated reference area cover. Shrub density was 3,261 shrubs/acre, exceeding the 2,000 shrubs/acre standard. With a MacArthur's Index value of 5.65, the reclaimed test plots came close to, but did not meet the 6.45 MacArthur's Index value of the diversity standard of the reference area. Erosion was reported to be moderate on the north-facing, steep (40%) slope. The report notes that in addition to the steepness of slope, there were few coarse fragments on the surface to stabilize the slope.

METHODS

This study was conducted on June 12, 2001. Five test pits were located on the top of the refuse pile, easily accessible by a track hoe. The concept of placing pits according to subsoil and topsoil cover depth placement was abandoned and replaced by the concept of locating pits immediately adjacent to shrub species of interest. An attempt was made to create corresponding pits in the subsoil storage area adjacent to the same shrub species. In some cases, pits were excavated between the roots of two different shrubs so, five pits yielded information on more than five shrub roots.

Refuse pits numbers 1 through 4 were located on level ground at the top of the refuse pile, within several feet of the test plot. Pit number 5 was on the outslope. Subsoil pits were located on a gentle slope with the higher pit numbers at the base of the slope.

Penetrometer resistance information was gathered from the pits on August 23, 2001. On that date, the refuse pits were either damp and muddy or had six inches of standing water in the bottom. The same was true for the subsoil pits, except that the subsoil pits at the base of the slope were completely submerged. This moisture proved fortuitous for the measurement of compressive strength of the soil.

The definitions of the descriptive terms used to quantify the roots and place them in a size class followed the procedures found in Schoeneberger et al, 1998. A copy of the Schoeneberger nomenclature has been included in this report as Appendix 1. In short, to describe the frequency of roots, the following terms are defined: "common" means 1 to < 5 per unit area; "few" means less than one per unit area; and, "very few" means less than 0.2 per unit area. The unit area evaluated depends upon the root size. To describe root size, the following terms are described: "very fine" roots are less than one millimeter in diameter; "fine" roots are between one and two millimeters in diameter; "medium" roots are between 2 to 5 mm in size; and "coarse" roots are 5 to 10 mm in size.

DISCUSSION

Refuse Pile

At the refuse pile, taproots of the following shrubs were exposed: three four-wing saltbushes (Atriplex canescens); four whitestem rubber rabbitbrushes (Chrysothamnus nauseosus var. albicaulis); one green stem rabbitbrush (Chrysothamnus nauseosus var. consimilis); one big sagebrush (Artemesia tridentata); one Mormon tea (Ephedra viridis). All taproots of the shrubs, except *Eriogonum corymbosum*[1], dramatically turned to grow along the soil/refuse interface before eventually descending gradually, but not vertically, into the refuse, see Picture #1. These tap roots were very gnarled, see Picture #2 versus Picture #3.

Picture #1, Refuse Pit #2. Taproot growing sideways. (The red portion of the Sharpshooter shovel is 18 inches long.)

Picture # 2, Refuse Pit #2. Gnarled roots.

Picture #3, Subsoil Pit #1. Normal roots

The soil and refuse were very dry and very hard to dig. The roots formed a mat of fine roots at the soil/refuse interface at Pit #2 south side, Pit #3 east and west sides, and Pit #4 north and south sides, for example see Picture #4. Within the refuse, root growth was noted in mats

[1] *Eriogonum corymbosum* was not seeded. It is a volunteer. It is often seen growing in coal outcrops.

underneath a large coarse fragments at Pit #2 south side and Pit #3 east and west sides and pit #5 south side. Few to very few medium and coarse roots were noted growing in the top two feet of the soil covered refuse at Pit # 1 east and west sides, Pit #2 south and north sides, Pit #4 south and north sides, and Pit #5 south side. Below two feet only few to very few medium and few to very few fine to very fine roots were noted in the refuse. (Very few medium roots were noted between 17 and 55 inches in Pit #2 north and south sides. There was no notation made to indicate whether the medium roots were located in the 17 to 24 inch zone or below 24 inches.)

Soil cover over the refuse varied from two inches on the slope at Pit #5 to eighteen inches at Pit #4. Soil field parameters were measured for the first two refuse pits (Pits #1 and #2) and the averages are reported in Table 4 below. Field measurements were hindered by variable saturated paste standing time and difficulty in drawing the filtrate off with suction.

Picture #4, Refuse Pit #2 south side
Mat of fine roots at the soil/refuse interface.

Table 4. Average field measurements for two refuse pits.

	Soil Cover	Soil/Refuse Interface	Refuse Composite
Estimated Texture	Clay loam	Loam	sand
Average pH	7.8	7.35	4.9 (ranged from 3.5 to 6.4)
Average color	Light brown	Peach/orange	black
Structure	Granular/platey	platey	massive
Resistance (dry)	3.0 Tons/sq ft		impenetrable
Resistance (moist)	1.2 Tons/sq ft		4.1 Tons/sq ft

Coarse fragments in the refuse were stained with iron and sulfur precipitates at four out of the five pits, suggesting some acid formation (see Picture #5). In response to testing with hydrochloric acid the refuse showed no effervescence, indicating that there are no carbonates present and it has no buffering capacity for any acidity it produces.

Picture #5, Pit #1 west side
Iron and Sulfur precipitation.

Picture #6, Pit #4 south side
Compacted Refuse

Refuse structure was massive and difficult to dig even with the trackhoe (see Picture #6, Pit #4 south side). The compaction of the refuse was noted by measuring the resistance to penetration with a pocket penetrometer. When the refuse was dry, it was impenetrable. When moist, it still presented a very hard surface requiring four times as much pressure to penetrate as the subsoil above it.

Subsoil Pile

At the subsoil pile, taproots of the following shrubs were exposed: two four-wing saltbushes (*Atriplex canescens*); two whitestem rabbitbrushes (*Chrysothamnus nauseosus* var. *albicaulis*); and two greenish rabbitbrushes (*Chrysothamnus nauseosus* var. *consimilis*). All shrub taproots were quite robust and grew straight downwards into the subsoil stockpile (see Picture #7)

Whereas roots growing into the refuse were generally fine to very fine in size, medium to coarse roots of plants were noted growing into the subsoil. At Pit #1 east side, very few, very coarse roots were noted and very few medium roots were noted. At Pit #3 east side, very few medium roots were noted. At Pit #4 south side, medium roots were common and coarse roots were few. At subsurface depths in Pit #5 east side, few medium to very few medium roots were noted. In fact, at Pits # 4 and # 5 at the base of the slope where moisture was encountered with depth, more roots of all sizes were noted at a depth of four feet.

At Pits #1 and #3 in the subsoil very few fine to very fine roots were noted clustered around a large rock (see Picture #8). This is similar to what was noted in the refuse.

Picture #7, Subsoil Pit #3
Taproot growing straight down into subsoil.

Picture #8, Subsoil Pit #
Roots clustered under rock in the subsoil.

Measured soil field parameters for the subsoil pile are reported in Table 5 below. At depths of seven to ten inches below the surface, the massive structure of the subsurface subsoil was encountered. Increasing moisture was noted with depth for pits at the base of the slope. However, at the top of the slope, hand digging of taproots was very difficult in the compacted, dry subsoil. The subsoil was impenetrable when dry, similar to the refuse. However, when it was moist, resistance to penetration was much lower than the refuse (2.16 tons/sq ft versus 4.1 tons/sq ft). The entire subsoil profile had a strong effervescent reaction indicating the presence of carbonates.

Table 5. Subsoil pile field measurements taken from Pit #3

	Surface	Subsurface
Estimated Texture	Clay to clay loam	Clay loam
Average pH	8.0	8.0
Average color	Brown	light brown
Structure	Fine platey	massive
Resistance (dry)	2.91 Tons/sq ft	impenetrable
Resistance (moist)	1.33 Tons/sq ft	2.16 Tons/sq ft

Volume measurements (length x width x height) were taken of shrubs at both the refuse and subsoil pit locations. The average volume for each site is reported in Table 6 below. No conclusions can be drawn from this information due to the extremely small sample size, the variation in topographic position, and the differential effects of grazing on growth at the sites.

Table 6. Average Above Ground Shrub Volumes in Cubic Feet

Shrub Volume	Refuse (sample size)	Subsoil (sample size)
Atriplex canescens	29.7 (2)	122 (2)
Chrysothamnus nauseosus var. *albicaulis*	49.8 (2)	21.4 (2)
Chrysothamnus nauseosus var. *consimilis*	68.3 (1)	42.0 (2)

CONCLUSIONS

The study of two plant growth medium types: coal refuse covered by substitute topsoil (or subsoil) and stockpiled subsoil (the same material used to cover the refuse) conducted at the Star Point Mine in central Utah provided the following facts:

- Rooting growth characteristics varied between refuse and subsoil.
- None of the shrub species in the study had a taproot that penetrated vertically into the refuse. Conversely, all the sampled shrub species in the subsoil pile had taproots that went vertically into the subsurface layer.
- The refuse was drier than the subsoil.
- The subsoil did not drain as freely as the refuse.
- Refuse had lower field pHs than the subsoil and higher ECs.
- When moist, refuse was more difficult to penetrate (almost twice as difficult) than the subsoil.
- Both subsurface subsoil and refuse were impenetrable when dry.
- Fine and very fine roots were observed at the four to five foot depth in

both subsoil and refuse.

- More coarse and medium roots were noted at comparable depths in the subsurface subsoil profile than the refuse profile.

Woody plant species became established in both growth mediums, but the roots reacted differently in each medium. Roots appeared to be better developed in the subsoil stockpile, including the development of well-defined taproots. In the refuse pile, roots grew straight downward until they came to the interface of the soil and refuse where they moved laterally before finally entering the refuse material. The research team concluded that the growth of taproots into refuse was atypical compared to growth of taproots into an adjacent subsoil stockpile of the same age or the available literature.

Compaction and moisture may have played a role in the differences. Compaction of refuse piles is required under Mine Safety and Health Administration regulations at 30 CFR 77.215 as a strategy to avoid combustion. As discussed earlier, Dames and Moore recommended a compaction of 75 pounds per cubic foot for the refuse material when it was placed in the test plot area of the refuse pile sometime between 1976 and 1982. A 1982 photograph of the refuse prior to installation of the test plot shows a two-track road going up the ridge of the pile. Our rooting depth study pits were in the same approximate location as the road. As demonstrated by the penetrometer readings the refuse remains well compacted, even when moist.

The difference between the penetration resistance of the refuse and subsurface subsoil, coupled with the location of the subsoil stockpile in a topographic position where precipitation run-on is likely (enhancing water availability), may well have accounted for the vertical taproot penetration into the subsurface subsoil compared to the refuse and the limited growth of medium and coarse roots into the refuse. The National Soil Survey Center (1996) advises that compacted soils can be identified by "platy or weak structure or a massive condition, greater penetration resistance, higher bulk density, restricted plant rooting, flattened, turned, or stubby plant roots." All of these conditions were noted in this study, with the exception of bulk density which was not measured.

Medium and coarse roots grew four to five feet deep in the subsoil stockpile, whereas medium and coarse roots were limited to the top two feet of the subsoil-covered refuse. Above two feet, the refuse would have been subject to freeze thaw forces which would reduce the bulk density and decrease compaction, creating a more conducive environment for medium and coarse root growth. To a lesser degree the ability of very fine roots to penetrate the refuse was also limited.

Although iron and sulfur staining was noted in most of the refuse pits, it is unclear if the lower pH had any effect on plant root growth, but the presence of fine and very fine roots in the refuse would indicate that they were not adversely affected by the refuse pH.

Root growth into soil-covered refuse would be enhanced by ripping of the surface prior to soil cover placement. The recommended depth of ripping is inversely related to the depth of cover, so that a less compacted root zone of four feet is achieved. If the refuse is combustible then the recommended soil cover depth should be four feet to allow for a rooting zone, while protecting against combustion. Working the soil cover into the refuse surface to avoid an abrupt boundary layer is also recommended.

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Schoeneberger, P.J. Wysocki, D.A., Benham, E.C., and Broderson, W.D. 1998 Field Book for describing and sampling soils. Natural Resources Conservation Service, USDA, National Soil Survey Center, Lincoln, NE , page 2-53, Footnote 1.

APPENDIX 1 **Root Quantity and Size Description**

from

Schoeneberger, PlJ. Wysocki, D.A., Benham, E.C., and Broderson, W.D. 1998 Field Book for describing and sampling soils. Natural Resources Conservation Service, USDA, National Soil Survey Center, Lincoln, NE, Page 2-53

ROOTS

Record the **Quantity**, **Size**, and **Location** of roots in each horizon. **NOTE**: Describe **Pores** using the same **Quantity** and **Size** classes and criteria as **Roots** (use the combined tables). A complete example for roots is: Many, fine, roots In Mat at Top of Horizon or 3**,** f (roots), ***M.***

ROOTS - QUANTITY (Roots and Pores) **-** Describe the quantity (number) of roots for each size class in a horizontal plane. (NOTE Typically, this is done across a vertical plane, such as a pit face.) Record the average quantity from 3 to 5 representative unit areas. **CAUTION:** The unit area that is evaluated varies with the Size Class of the roots being considered. Use the appropriate unit area stated in the *Soil Area Observed* column of the "Size (Roots and Pores) Table". In NASIS and PDP, record the actual number of roots/unit area (which outputs the appropriate class). Use class names in narrative description.

Quantity Class[1]	Code Conv	NASIS	Average Count [2] (per unit area)
Few Very Few Moderately Few	1 - -	#	< 1 per area < 0.2 per area 0.2 to < 1 per area
Common	2	#	Common 1 to < 5 per area
Many	3	#	= 5 per area

1 The Very Few and Moderately Few sub-classes can be described for roots (optional) but do not apply to pores.

2 The applicable area for appraisal varies with the size of roots or pores. Use the appropriate area stated in the *Soil Area Assessed* column of the "Size (Roots and Pores) Table" or use the following graphic.

ROOTS - SIZE (Roots and Pores) **- *See*** the following graphic for size.

Size Class	Code Conv	NASIS	Diameter	Soil Area Assessed[1]
Very Fine	vf	VF	< 1 mm	1 cm^2
Fine	f	F	1 to < 2 mm	1 cm^2
Medium	m	M	2 to < 5 mm	1 dm^2
Coarse	co	C	5 to < 10 mm	1 dm^2
Very Coarse	vc	VC	= 10 mm	1 m^2

1One dm^2 = a square that is 10 cm on a side or 100 cm^2